Testing Concrete and Mortar Interference in Throughput Levels of Urban Indoor Wi-Fi IEEE 802.11 Networks

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Summary:
This paper describes a procedure that can be used to test IEEE 802.11 wireless network throughput performance, under most common typologies of concrete and mortar, present in indoor urban environments. Inside buildings, due to the usage of different elements in construction, the walls, ceilings and floors are able to cause interferences and data flow degeneration on IEEE 802.11 Wi-Fi indoor data transmission. Results are presented, from tests carried out using a notebook and a reduced hardware smartphone as network clients with 16 obstacles derived from four distinct typologies of concrete and mortar.
Keywords:
Wireless Networks, IEEE 802.11, Quality of Service, Data Throughput, Typologies of Concrete and Mortar.

1. Introduction

Lately, the field of communications technology, followed by the progress of media and transmission techniques to internet access, has evolved to allow mobile wireless data transmission in urban systems. That favored the widespread of wireless networks in urban areas, mostly making usage of the IEEE 802.11 standard, in portable electronic devices such as lap-tops, TVs, smart phones, tablets and others. The spread of such devices, associated to the fact that there are people who have more than one device activated simultaneously, means that the wireless transmission system must be accordingly robust. In this context, the IEEE 802.11 standard presents a quality profile and performance [2] that justifies its use in such conditions.

The actual use of these devices occurs within buildings, whether during working business hours or inside homes, where people live. So, the wireless transmission is always subject to the influence of walls, ceilings and floors. These elements can be made, for example, of concrete, reinforced concrete, grout or mortar. Consequently, typologies of concrete and mortar, present in urban environments, are able to cause interferences on the radiation transmission levels of IEEE 802.11 Wi-Fi [3, 9] that can lead to both data flow throughput and energy consumption degeneration [3, 9, 10, 11].

Concerning urban built environments, specifically the buildings construction presented a significant enhancement from the development of the cement, occurred in the mid-nineteenth century in France. Also worthy of note is the use of additional equipment in the concrete that became known as reinforced concrete. Regarding the mortar and reinforced mortar, their development is marked in 1849 in an experiment where LAMBOT built a small boat using cement, sand, water and steel wire [7]. Nowadays, the buildings in urban areas are made, mostly, making use of concrete, reinforced concrete, mortar, reinforced mortar, and ceramic blocks. It is important to note that, regardless of the structure of the buildings, they all have users of wireless transmission systems, either with cell phones, lap-tops or other reduced hardware devices [8].

Therefore, the purpose of this paper is to analyze the data flow throughput of indoor IEEE 802.11 wireless networks transmission in portable computers (such as laptops), and reduced hardware devices (such as smart phones), in indoor built environments, with walls, ceiling and/or floor made of the most representative types of concrete and mortar, widespread used in urban areas.

2. Methodology

The set-up tests used different components. Firstly, a DELL computer with Intel processor - Dual Core was used as access point (AP) server, assembled with a 2.4 GHz antenna and a Wi-Fi signal router. The operational system adopted was Linux Ubuntu. Also, one lap-top computer, HP Compaq 6910p, with Intel Centrino processor type - Pro, was used as a station. Similarly, other station was configured with an LG smart phone with Android operating system.

As obstacles to the radio signal propagation, four slabs of 20 cm high and 20 cm wide were employed. The first was

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a board of pure concrete with thickness equals to 10 cm; the second, a slab of concrete with thickness of 10 cm, reinforced with steel wire in a 5-cm spaced grid; next, a plate of pure mortar with a thickness of 5 cm and, finally, a reinforced mortar board of 5 cm thick with steel wire in a 1-cm spaced grid. The obstacles (single boards or two board sets) were positioned between the access point and one of the stations, in a intensive data exchange condition, where the influence on data throughput was observed.

The data traffic was monitored with Iperf software [12], which was responsible for data packet injection into the system. In this case, the computer with the Wi-Fi antenna worked with the software in server mode. Consequently, the lap-top and the smart phone operated with the software in client mode, acting as transmission clients during the tests. The Iperf software was configured to operate in the range of 108 MB/s, which was twice the capacity of the communication channel, in order to saturate the channel.

The tests were divided into two groups: in the first group, only one prototype board was positioned before the client that alternated between lap-top client and smart phone client; in the second group, two prototype boards were employed, positioning one just after the other between access point and client. Also in this case, the client was switched between the between lap-top and smart phone during the tests. Table 1 that illustrates the division of groups and the setting of the mortar and concrete boards.

Table 1 - Division of groups and setting of the boards during tests

1st Group - Obstacle Boards Configuration
1- Concrete
2- Reinforced Concrete
3- Mortar
4-Reinforced Mortar
2nd Group - Obstacle Boards Configuration
1- Concrete and Reinforced Concrete
2- Concrete and Mortar
3-Concrete and Reinforced Mortar
4- Reinforced Concrete and Concrete
5- Reinforced Concrete and Mortar
6- Reinforced Concrete and Reinforced Mortar
7- Mortar and Concrete
8- Mortar and Reinforced Concrete
9- Mortar and Reinforced Mortar
10- Reinforced Mortar and Concrete
11- Reinforced Mortar and Reinforced Concrete
12- Reinforced Mortar and Mortar

All possible configurations of the two groups were exposed to the test system for 3 minutes, with the two clients (laptop and smart phone). The Iperf sampling system collected traffic data characteristics from the network every one-second, thus resulting in 180 measurements for each individual configuration of the testing environment. Figure 1 illustrates the tests configuration in the 1st group, and Figure 2 illustrates how the tests occurred in the 2nd group.

Figure 1 - Test Configuration in the 1st group

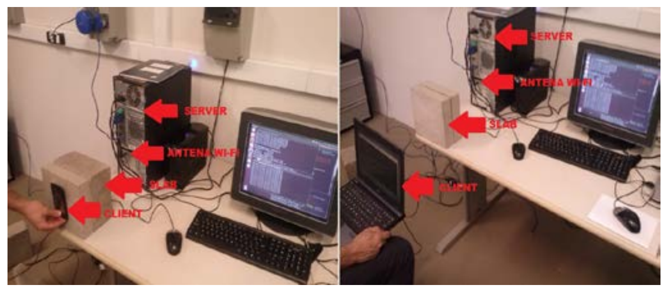

Figure 2 - Test Configuration in the 2nd group

3. Results

After the assessment of the collected data, an analysis for data flow throughout between stations and AP in each configuration was performed. This assessment included statistical parameters analysis that included average flow, flow standard deviation, maximum and minimum data flow for the data extracted during each transmission test. The analysis was conducted both for the smart phone and the laptop in client mode scenarios, and also considering the two configuration groups of mortar and concrete sample plates as obstacles to the transmission of data. The results of the analysis are present in Table 2.

Accordingly to the data presented in Table 2, and considering the general average of the results, the configuration composed by two plates of samples presented the greatest change in the signal flow (Mbps) with the Wi-Fi IEEE 802.11 standard, for test trials in the case using the smartphone configured as a client. To better illustrate the results, figures 3, 4, 5 and 6 present a comparative throughput performance for the two proposed test configurations.

Table 2 – Average Flow for different configurations

Analysis of Flow										
	SMARTPHONE					LAPTOP				
1º Group										
Setting Boards	Average Flow (MB/s)	Standard Deviation	Variance	Maximo	Minimum	Average Flow (MB/s)	Standard Deviation	Variance	Maximo	Minimum
1- Concrete	29,61	0,55	0,30	30,38	27,12	29,78	2,41	5,81	30,63	15,35
2- Reinforced Concrete	29,26	1,88	3,53	30,09	5,68	29,43	3,42	11,70	30,60	6,30
3- Mortar	29,43	0,60	0,36	30,33	26,98	26,55	7,12	50,69	30,61	7,09
4-Reinforced Mortar	29,32	0,58	0,34	30,27	25,65	29,52	2,85	8,12	30,58	13,75
Averege Values	**29,41**	**0,90**	**1,13**	**30,27**	**21,36**	**28,82**	**3,95**	**19,08**	**30,61**	**10,62**
2º Group										
Setting Boards										
1- Concrete and Reinforced Concrete	28,91	0,77	0,59	29,80	25,20	29,08	3,21	10,30	30,63	14,65
2- Concrete and Mortar	28,17	2,44	5,95	29,79	8,74	29,36	3,39	11,49	30,62	11,77
3-Concrete and Reinforced Mortar	28,28	2,14	4,58	29,89	5,30	29,57	2,80	7,84	30,57	15,11
4- Reinforced Concrete and Concrete	28,73	0,77	0,59	30,07	23,80	27,07	7,25	52,56	30,64	8,23
5- Reinforced Concrete and Mortar	29,35	0,50	0,25	30,19	27,24	29,27	3,40	11,56	30,64	13,99
6- Reinforced Concrete and Reinforced Mortar	28,86	1,51	2,28	30,24	13,51	29,52	3,24	10,50	30,73	10,07
7- Mortar and Concrete	29,17	1,20	1,44	30,06	16,78	27,79	5,56	30,91	30,55	11,33
8- Mortar and Reinforced Concrete	28,56	1,93	3,72	30,35	15,77	29,42	2,94	8,64	30,50	13,45
9- Mortar and Reinforced Mortar	29,35	0,67	0,45	30,29	25,44	29,47	2,94	8,64	30,61	13,79
10- Reinforced Mortar and Concrete	29,33	0,61	0,37	30,23	26,81	29,21	3,28	10,76	30,53	12,04
11- Reinforced Mortar and Reinforced Concrete	29,22	0,85	0,72	30,12	20,58	29,38	2,83	8,01	30,53	15,14
12- Reinforced Mortar and Mortar	29,22	0,56	0,31	30,22	26,94	29,19	3,06	9,36	30,62	14,38
Averege Values	**28,93**	**1,16**	**1,77**	**30,10**	**19,68**	**29,03**	**3,66**	**15,05**	**30,60**	**12,83**
Comparing Group 2 with Group 1	2%	29%	56%	-1%	-8%	1%	-7%	-21%	0%	21%

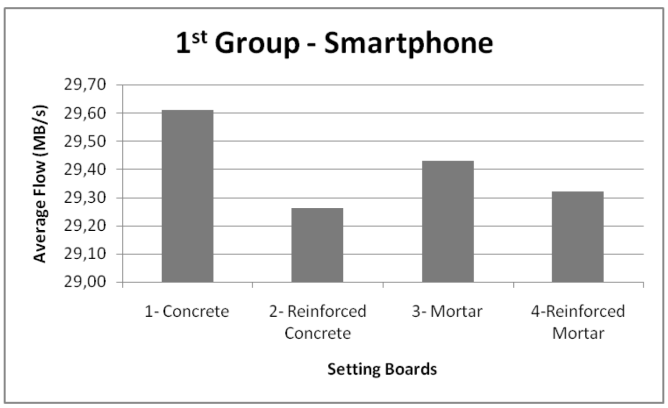

Figure 3 – 1st group comparative power performances for Smartphone client

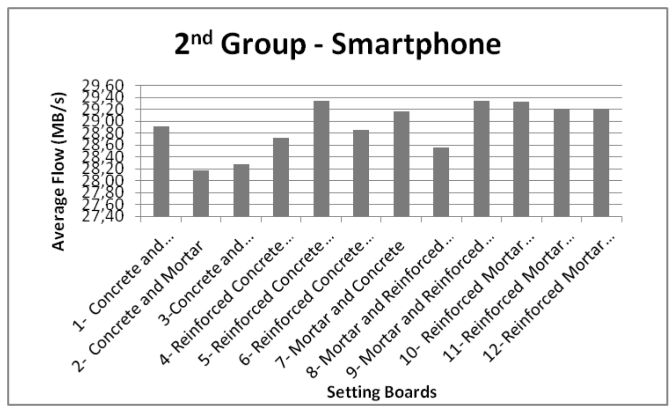

Figure 5 – 2nd group comparative power performances for Smartphone client

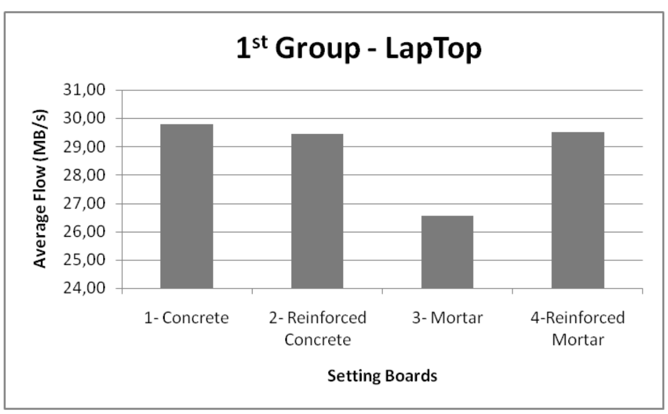

Figure 4 – 1st group comparative power performances for Laptop client

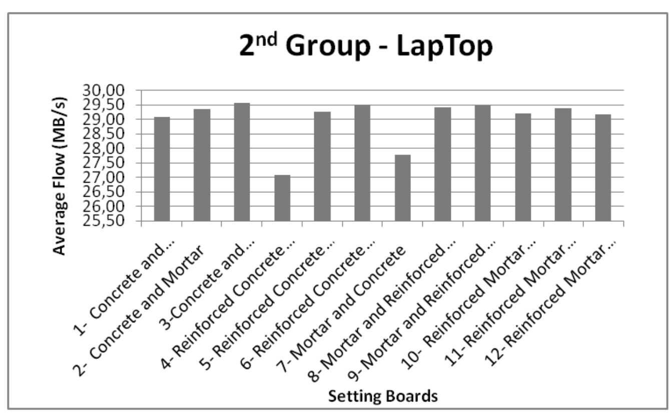

Figure 6 – 2nd group comparative power performances for Laptop client

Conclusion

The tests make possible to conclude that there can be significant variation in the signal flow throughput (MBps) in IEEE 802.11 indoor networks, depending on the construction materials used to build walls, ceilings and floors. The tests were carried out for the most common typologies of concrete and mortar present in urban environments. Radio signal based information and, in special, IEEE 802.11 standard based communications represent a promising technological approach to make feasible the necessary actions involved in future smart-grids and smart-cities operations in the Internet of Things context. Considering that buildings have a lifecycle of several decades, that fact must be taken into account during the building construction and materials selection in order to minimize radio signal interferences. Moreover, the obtained results permit to conclude that the throughput degeneration depends on the client type, and is more severe for reduced hardware mobile devices when configured as clients in an IEEE 802.11 standard wireless network. Considering modern technological tendencies, this degeneration differentiation is also a fact that must be of concern when building materials are selected, in order to avoid the necessity of additional infrastructure that, despite representing a small value in the construction budget, will be responsible for a large additional energy consumption and unnecessary electromagnetic emission in the long term.

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